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Forest Health Protection
Pacific Southwest Region
Northeastern California Shared Service Area

Date: August 3, 2018
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To: District Ranger, Beckwourth Ranger District, Plumas National Forest

Subject: Evaluation of stand conditions with respect to forest insects and disease within the Mapes project, Plumas National Forest (FHP Report NE18-09)

At the request of Paul Czeszynski, Silviculturist, Beckwourth Ranger District, Danny Cluck, Forest Health Protection (FHP) Entomologist, visited the Mapes project on June 21, 2017 and again on May 3, 2018. The objective of these visits was to evaluate current stand conditions, determine the impacts of forest insects and diseases on management objectives and discuss proposed alternatives. Recommendations provided in this report will assist in the formulation of silvicultural prescriptions aimed at reducing stand density and increasing resiliency to disturbance agents such as fire, insects and diseases.

Key Findings

- High stand density is putting many stands at risk to high levels of bark beetle-caused tree mortality during periods of drought. Many of these same stands are also at risk to high severity wildfire.
- Elevated levels of recent white fir mortality associated with drought, disease and fir engraver beetle are common wherever white fir is growing within the project area.
- White pine blister rust is infecting sugar pine in mixed conifer locations, increasing the susceptibility of mature trees to bark beetle attack and negatively impacting regeneration.
- Dwarf mistletoe infection levels are high in some Jeffrey and ponderosa pine stands reducing tree vigor and predisposing trees to bark and woodboring beetle attacks.
- Thinning and prescribed fire are highly recommended throughout the project area to reduce tree density and decrease surface and ladder fuels. Specific recommendations are provided in this evaluation.

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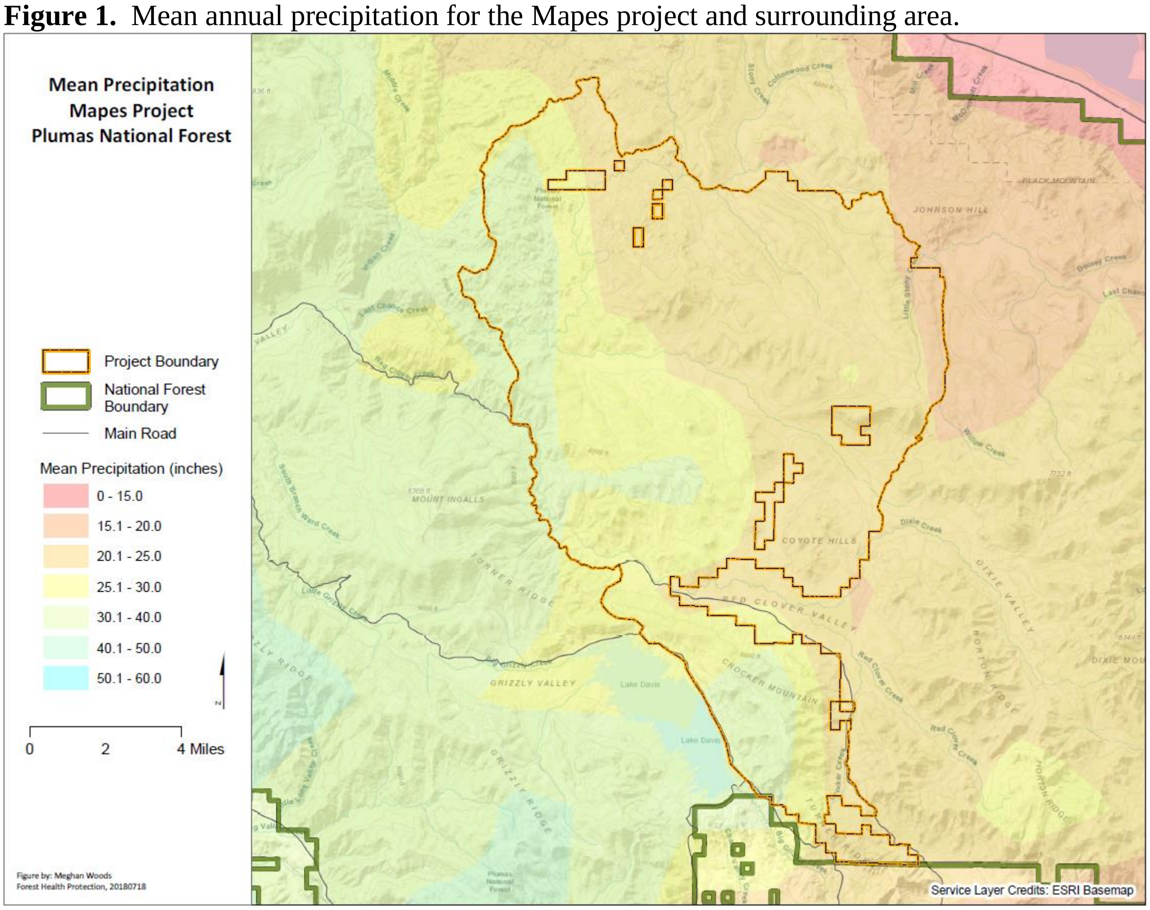
Description of the project area

The center of the Mapes project area is located 12 miles north Portola, CA (39.992407N and 120.480936E). The elevation ranges from 5,400 – 7,400 feet with annual precipitation ranging between 18 and 35 inches (Figure 1). A few upper elevation and north facing slope locations within the project area contain stands of Sierra Nevada mixed conifer type consisting of the following species: white fir (*Abies concolor*), incense cedar (*Calocedrus decurrens*), Jeffrey pine (*Pinus jeffreyi*), ponderosa pine (*Pinus ponderosa*), sugar pine (*Pinus lambertiana*) and Douglas-fir (*Psuedotsuga menziesii*). Lower elevations and south facing slopes are dominated by ponderosa and Jeffrey pine with incense cedar, white fir and western juniper (*Juniperus occidentalis*). There are also aspen stands (*Populus tremuloides*) associated with riparian areas. Many acres within the project area consist of stands of western juniper, meadows or sagebrush flats.

Management objectives

The Mapes project proposes to reduce the risk of insect and disease-caused tree mortality through mechanical thinning. Fuels reduction and maintenance would also be accomplished with mastication and prescribed burning. White fir will be removed in favor of retaining other tree species in mixed conifer stands. Residual stands will be more open, increasing the amount of available soil moisture and sunlight for individual trees.

Figure 1. Mean annual precipitation for the Mapes project and surrounding area.



Forest insect and disease conditions

Incense cedar rust (*Gymnosporangium libocedri*) was observed on incense cedar in several locations near Lake Davis.

White fir dwarf mistletoe (*Arceuthobium abietinum f. sp. concoloris*) is present in portions of the project area in both overstory and understory white fir.

Figure 2. Dead and down white fir with delaminated decay associated with Heterobasidion root disease, Mapes project, 2017.

Heterobasidion root disease (*Heterobasidion occidentalis*, formerly referred to as S-type annosus root disease) was found infecting white fir in several locations as indicated by the presence of conks, delaminated decay on the roots of windthrown snags, stunted leader growth of infected trees and recent top-kill and whole tree mortality associated with the fir engraver beetle (*Scolytus ventralis*) (Figures 2 and 3).

Figure 3. White fir mortality and top-kill caused by Heterobasidion root disease and fir engraver beetle, Mapes project, 2017.

Several areas with elevated white fir mortality were also mapped in 2017 during the annual tree mortality aerial detection survey (Figures 4 and 5).

White pine blister rust (*Cronartium ribicola*) was observed in sugar pine causing branch flagging and top-kill (Figure 6).

Jeffrey pine mortality, caused by heavy western dwarf mistletoe (*Arceuthobium campylopodum*) infections and attacks by California flatheaded borer (*Phaenops californicus*), was observed in a stand near Lake Davis (Figure 7).

Western dwarf mistletoe was also found in ponderosa pine. Several infected trees had been recently attacked and killed by western pine beetle (*Dendroctonus brevicomis*).

Stand conditions and mortality related to recent and future climate trends

Many of the stands within the Mapes project appear to be at or above "normal" stocking levels and have exhibited elevated levels of tree mortality caused by bark beetles during and after

Figure 4. Areas with aerially mapped tree mortality in 2017 within the Mapes project.

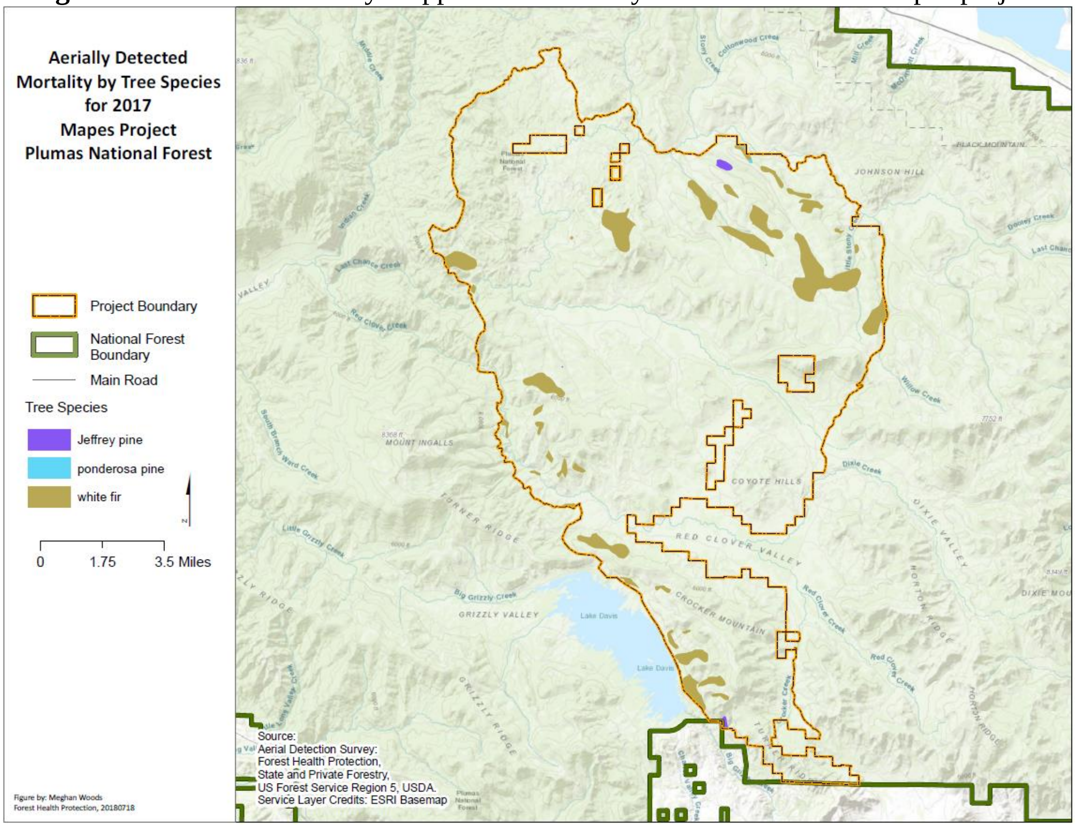


Figure 5. Scattered white fir mortality within the Mapes project in 2016 (ADS photo)

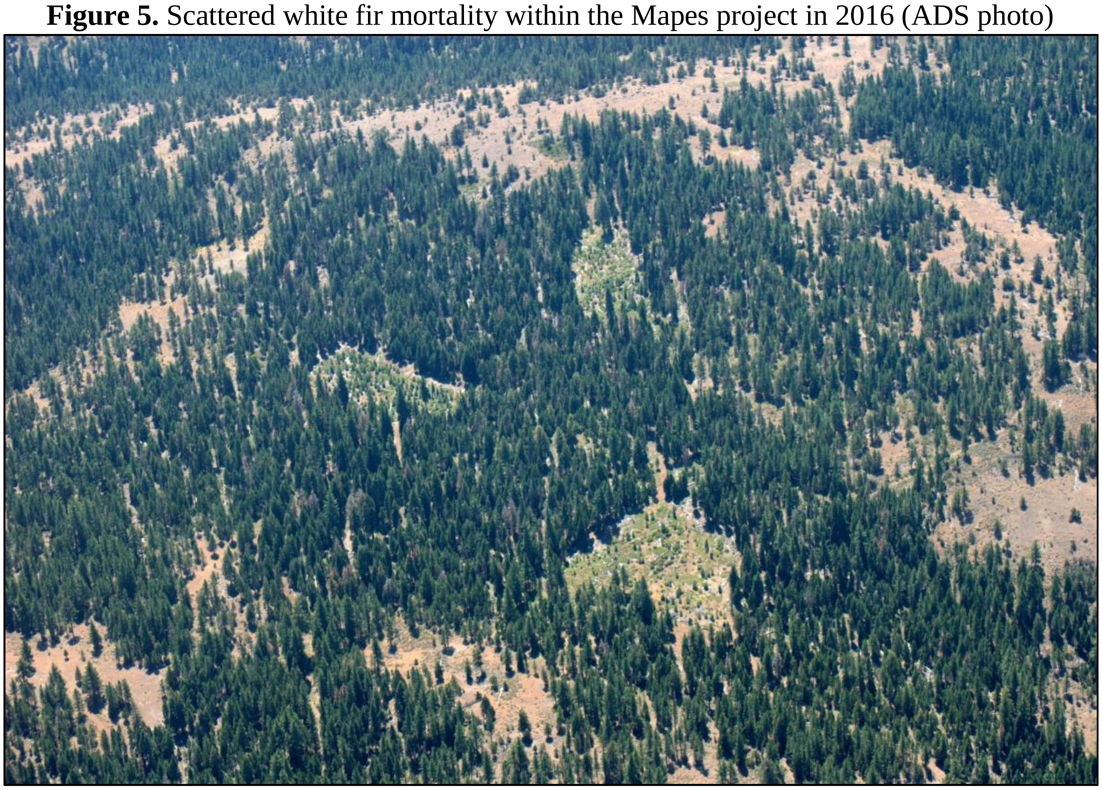
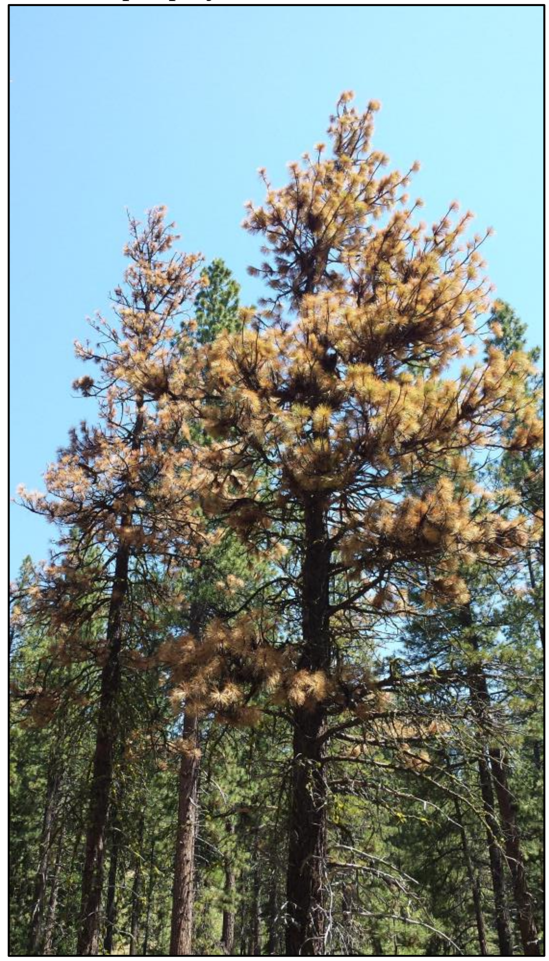


Figure 6. Top dieback on sugar pine caused by white pine blister rust, Mapes project, 2017.

Figure 7. Western dwarf mistletoe infected Jeffrey pine killed by California flatheaded borer, Mapes project, 2017.



periods of drought (Figures 8 and 9, Table 1). This mortality combined with high stand density has resulted in heavy fuel loading in some areas and a corresponding increase in potential fire behavior.

Tree mortality attributable to insects and/or pathogens is elevated throughout the project area and has increased over the past two years (Table 1). Elevated levels of tree mortality in this area, as well as in the rest of the Sierra Nevada range, are strongly associated with periods of below normal precipitation and high stand density. Successive dry years can exacerbate unhealthy stand conditions, such as those that exist within the Mapes project; resulting in higher levels of bark beetle-caused tree mortality. The Palmer Hydrologic Drought Index is also included in Table 1 to show the relationship between drought and tree mortality. The high number of dead trees mapped in 2017 were mostly white fir that were attacked by fir engraver beetle in 2016 before the wet winter of 2016/2017. There are also many dead and down white fir throughout the project area that were killed by fir engraver beetle during previous droughts. These outbreaks also created numerous top-killed white fir.

Figure 8. Areas of tree mortality and dead trees per acre mapped by ADS between 2008 and 2017

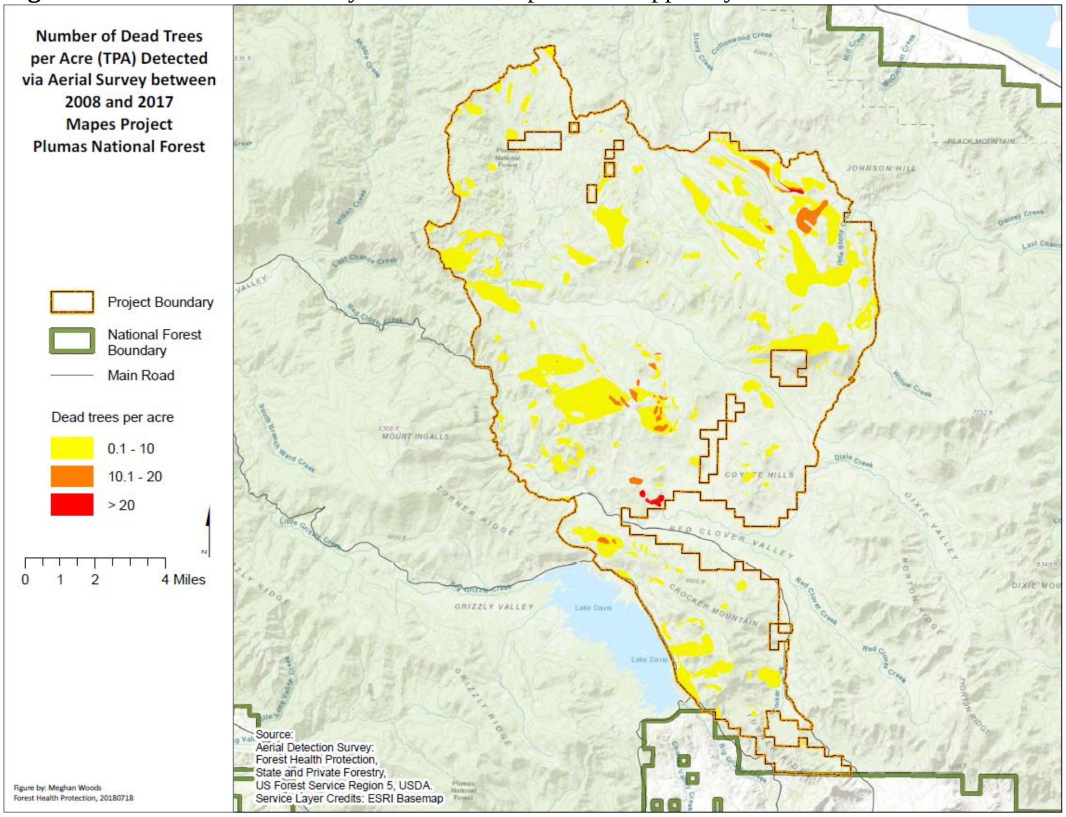


Figure 9. Number of years with elevated tree mortality mapped by ADS between 2008 and 2017.

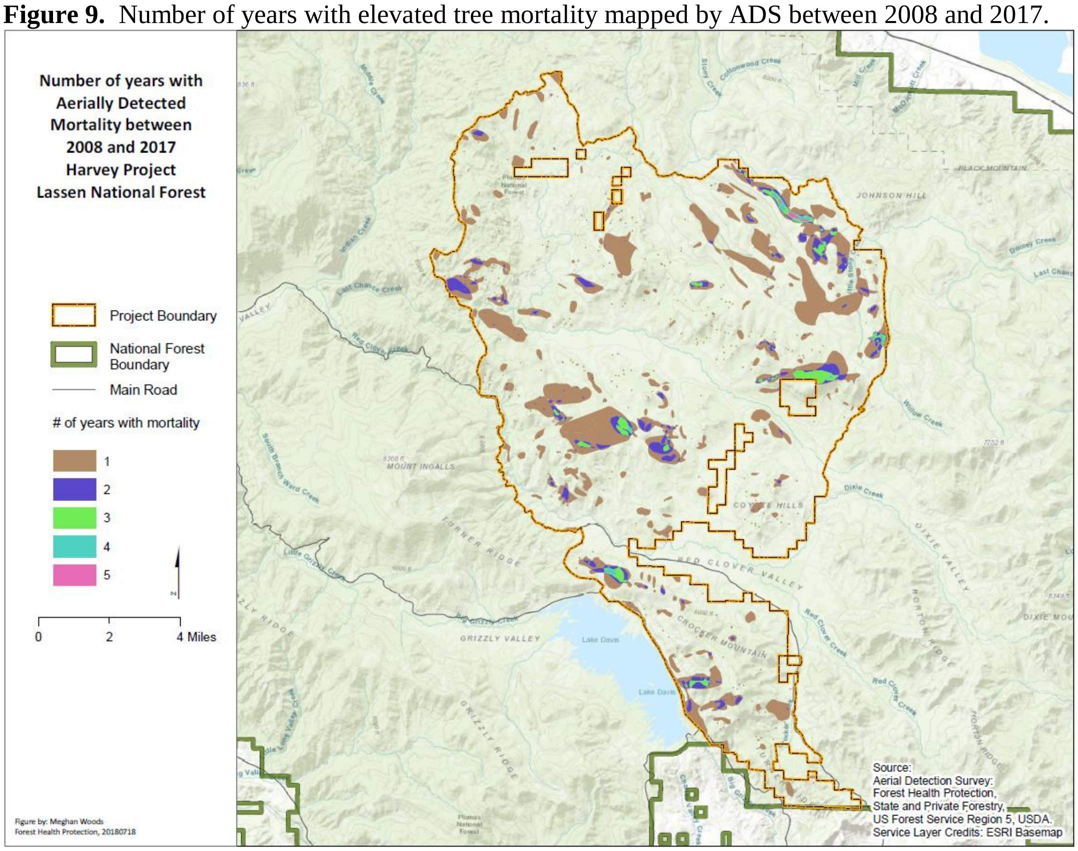


Table 1. Acres with mortality, estimated dead trees per acre and estimated total # of dead trees from R5 Aerial Detection Surveys and Palmer Hydrologic Drought Index (PHDI) (average of CA Divisions 2 and 3[1]) by water year (Oct-Sept) within the Mapes project area.

Year	Acres	Dead Trees/Acre	Total # of Dead Trees	PHDI[2]
2017	4,246	2.2	9,307	3.00
2016	2,645	2.0	5,237	-1.32
2015	353	3.6	1,276	-3.34
2014	199	2.0	404	-3.56
2013	419	1.2	484	-2.16
2012	830	3.1	2,596	-0.59
2011	2,289	2.2	4,951	2.78
2010	2,196	6.7	14,630	-0.14
2009	2,769	1.8	5,030	-2.98
2008	263	1.3	348	-3.16

[1] California Divisions 2 and 3 encompass most of northeastern California.
[2] PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions. Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

White fir that succumb to fir engraver beetle attacks are typically predisposed by other factors that compromise their health and vigor. In the Mapes project area, high stand density, prolonged drought, trees growing off site, dwarf mistletoe and Heterobasidion root disease are all contributing factors in declining tree health and mortality.

The distribution of both white fir and white fir mortality are strongly influenced by the mean annual precipitation. The lower limit of precipitation in the natural range of white fir is about 20 inches (Fowels, H.A. 1965). The isohyetal map of mean annual precipitation provided in this report (Figure 1) can be used to rate the risk of white fir mortality (Schultz 1994).

<u>Low risk: 40+ inches annual precipitation **(~0% of Mapes Project**).</u> These areas easily support stands of white fir. Mortality will be low, even during drought periods. Thinning will increase the rate of tree growth, but will show only slight differences in tree mortality.

<u>Medium Risk: 30-40 inches of annual precipitation **(~16% of Mapes Project**).</u> Stands in these areas often have a high percentage of white fir that may achieve a considerable age and size. Prolonged drought may cause mortality of 5-10% of the stems. Periodic thinning which concentrates on removing white fir ingrowth will lower mortality by maintaining a more sustainable amount of biomass, as well as promoting a more stable mixed species stand.

<u>High Risk: 25-30 inches of annual precipitation **(~34% of Mapes Project**).</u> In the absence of fire, these areas have stands which are dominated by densely stocked, small diameter white fir. The species distribution by age class shows an increase in the relative percentage of white fir in these stands following fire suppression. Prolonged drought may cause mortality in excess of 50% of the stems. The risk of mortality can be lowered by thinning to a wide spacing prior to the onset of drought, and by promoting a mix of species that are native to the site.

Extreme risk: 20-25 inches of annual precipitation **(~50% of Mapes Project**). In some cases the shade tolerant trees may live long enough to achieve an intermediate or co-dominant crown position. Prolonged drought may cause mortality of 80-85% of the stems. In stands where the total stocking of both overstory and understory is high, mortality may also occur in the pines. The risk of mortality may be lowered by managing groups of pine at wide spacing.

Nearly all of the project area receives less than 30 inches of annual precipitation and no area receives more than 40 inches. Thirty inches is below what is generally required for healthy white fir forests to exist over the long-term. Therefore, even at the lowest stocking levels, white fir growing on these sites are at a high to extreme risk for fir engraver beetle-caused mortality during periods of drought. Even in stands that receive between 30 and 40 inches, the risk of mortality during drought is still considered medium.

In mixed conifer areas, dense stand conditions and an abundance of white fir appear to have reduced the amount of regeneration of shade intolerant species. The distribution and species composition of old growth trees and stumps remaining within these portions of the project area (mostly IC, SP, DF, PP, JP) suggests that stands were more open in the past, maintained by frequent low severity fire, with fewer white fir.

Eastside pine stands are overly dense in many locations and have experienced high levels of tree mortality during past droughts as evidenced by pockets of old dead and down trees killed by bark beetles. Some stands have very high levels of western dwarf mistletoe infections that are reducing growth and increasing the risk of tree mortality.

Predicted climate change is likely to impact trees growing in the Mapes area over the next 100 years. Although no Plumas National Forest specific climate change models are available at this time, there is a general consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (K. Merriam and H. Safford, *A summary of current trends and probable future trends in climate and climate-driven processes in the Sierra Cascade Province, including the Plumas, Modoc, and Lassen National Forests*. The risk of bark beetle-caused tree mortality will likely increase for all conifer species under this scenario, especially drought intolerant white fir with high levels of disease. Improving the resilience of stands to future disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested landscape. Anticipating future drought events and reducing tree density to levels that are more resilient and sustainable should reduce the risk of unacceptable levels of tree mortality within the Mapes project area.

Considerations for thinning treatments

Most of the thinning treatments proposed by the District should reduce stand density to a level that significantly lowers the risk of bark beetle caused mortality. In most cases, thinning to a relative density of 25 - 40% (relative to the maximum Stand Density Index, or SDI) for a specific conifer species or for a weighted composition of conifer species will effectively reduce competition for limited water and nutrients and reduce the susceptibility to future bark beetle-caused tree mortality for many years. The District should consider an SDI max of 450 for drier

pine-dominated mixed conifer (Long and Shaw 2005). For eastside pine stands, the District should consider using the limiting stand density index (SDI) of 365. SDI 365 is considered the upper management zone for ponderosa pine above which bark beetle outbreaks are likely to occur and SDI 230 is the defined threshold for the zone of imminent bark beetle caused mortality (Oliver 1995). Reducing the SDI in ponderosa/Jeffrey pine dominated stands to below 230 is highly recommended. Thinning stands to this level will reduce the risk of additional bark beetle-caused mortality by reducing tree competition for limited water and nutrients.

The latest peer-reviewed research on Jeffrey pine stocking as it relates to Jeffrey pine beetle-caused mortality (Egan et al 2016) and a FHP report for the same study (Egan et al 2009) suggest stocking levels that are at or below SDI 210 (corresponded to < 125 sq.ft./acre of basal area in study plots) to reduce tree mortality during droughts and high bark beetle population pressure. Stocking levels of SDI 110 (corresponded to <80 sq.ft./acre of basal area in study plots) had no Jeffrey pine beetle-caused mortality during the Jeffrey pine beetle outbreak monitored during the study.

Many stands contain large diameter ponderosa, Jeffrey and sugar pine. Thinning treatments that improve growing conditions for these legacy trees would increase their health and vigor, create opportunities for their successful regeneration and improve overall resiliency to disturbance agents (insects, disease, drought and fire). Removing competing trees from the base of large diameter pines combined with stand level thinning has resulted in a measured increase in annual increment growth in old growth ponderosa and Jeffrey pine on the Lassen National Forest (Hood et al 2017).

When planning thinning treatments, it should be recognized that the target stand density is an average to be applied across the landscape and some variability may be desired. Individual high value trees, such as mature pines, should benefit by having the stocking around them reduced to lower levels. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees, or on more mesic north-facing slopes. Incorporating the concepts of GTR 220 will address many of these issues and be consistent with Regional ecosystem restoration goals. Many of these methods are also consistent with past FHP recommendations for thinning in mixed conifer and eastside pine stands and their use is supported for the Mapes project.

The presence of Heterobasidion root disease in white fir, should be considered when developing silvicultural prescriptions. Root diseased white fir are at a higher risk for fir engraver attacks than uninfected trees during droughts. Leaving high numbers of root diseased trees will likely lead to higher levels of mortality over the long-term, reducing large tree canopy cover and increasing fuels. Leaving these trees will also reduce opportunities for successful regeneration of shade intolerant species that are not susceptible hosts to *H. occidentale*.

The best option for managing *H. occidentale* in white fir is to reduce its overall abundance in the stand and remove severely infected trees. Various sized openings can be created in the stand to facilitate planting of non-hosts such as ponderosa, Jeffrey and sugar pine. Placing these openings on known or suspected root disease pockets will enhance the effectiveness of this strategy for reducing overall infection levels. In addition, greatly reducing white fir stocking in stands that

have a non-host overstory component will allow for natural non-host regeneration and create a more resilient species composition over time.

Effectively managing dwarf mistletoe infection levels within pine stands will require the removal or killing of heavily infected trees. Young ponderosa or Jeffrey pine establishing under an infected overstory will most likely become infected and not reach maturity. It may be desirable to remove or kill infected overstory trees from some areas to allow for healthy stand regeneration (natural or artificial). Removal of all heavily infected trees, especially heavily infected trees in the overstory, combined with general stand thinning will reduce the spread of mistletoe to insignificant levels while increasing the health and vigor of trees with light infections.

It is important when thinning pine stands to be aware of the potential for pine engraver beetle (*Ips pini*) populations to increase in green slash. Ips populations can build up within green pine slash (>4" in diameter) in the spring and successfully attack and kill adjacent pines later in the summer. Mortality to residual pines from *Ips* beetle attacks in California have mostly been associated with green slash in the form of doodle piles or small hand piles that are left scattered throughout the stand in close proximity to residual trees. The risk of subsequent tree mortality increases with drier than normal conditions and when the green material is longer in length and/or is of a larger diameter that can prevent rapid drying.

Normally, green pine slash, doodles and/or hand piles created from July through early fall (mid-October) will not be conducive to significant Ips population build up. Also, based on past observations of pine engraver beetle activity on the eastside of the Sierra Nevada and Cascade mountain ranges, having pine slash, biomass and sawlogs consolidated into large piles at landings has not resulted in subsequent tree mortality, regardless of timing. If harvest activities are to occur from late fall through early summer (November-June), any green pine material should be removed from the stand, treated (chipping or burning) or consolidated onto landings by the following spring.

It is recommended that a registered borate compound be applied to all freshly cut conifer stumps >14" in diameter to reduce the chance of creating new infection centers of *Heterobasidion irregulare* and *H. occidentale* formerly referred to as P-type and S-type annosus root disease, through harvest activity. An exception to this recommendation would be to not treat white fir stumps in mixed conifer stands if there is already a high level of Heterobasidion root disease present as treating white fir stumps in heavily infected stands is ineffective.

Sugar pine should be retained as much as possible during any thinning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. An exception to this would be thinning suppressed trees within pure sugar pine groups to reduce inter-tree competition. White pine blister rust, a non-native pathogen, has continued to weaken and kill this species over most of its range since its introduction into the Pacific Northwest in 1910. Identification and protection of local rust resistant trees for seed collection, if not already occurring, will aid in the future planting of rust resistant seedlings. Planting selected openings created through thinning operations with rust resistant stock would help insure this species persists in the area.

Forest Health Protection recently developed a treatment priority map for Region 5 to help land managers prioritize thinning treatments at the landscape level. This map depicts forested areas on National Forest System lands that are the most susceptible to drought and bark beetle-caused tree mortality based on forest type and stand density. These areas also meet the criteria of existing on slopes <=35% and being outside of wilderness areas, wild and scenic river corridors, designated roadless areas and California spotted owl protected activity centers. Additional criteria include not having burned at moderate to high severity since 1998 and not having been thinned since 2005. In addition to being overly dense, these areas have a history of tree mortality during drought resulting in heavy fuel loads and higher risk of stand replacing wildfire. Highest priority areas consist of high density pine stands, pine-dominated mixed conifer stands and fir-dominated mixed conifer and white fir stands growing on historically pine dominated sites. Second priority areas consist of high density fir-dominated mixed conifer and white fir stand on wetter sites. All mapped stands are California Wildlife Habitat Relationship size class 4, 5 and 6.

Figure 10 shows treatment priority areas within the Mapes project boundary. This mapping effort utilized remotely sensed data to create treatment priority layers for large scale planning and may not be accurate at the stand level. The forest should still use stand records and stand exam data to identify treatment areas and develop silvicultural prescriptions. An ALL LANDS version of the map was also created that includes wilderness areas, wild and scenic river corridors, designated roadless areas and California spotted owl protected activity centers to evaluate stand conditions in these protected areas. It also includes slopes >35% and all land ownerships (Figure 11).

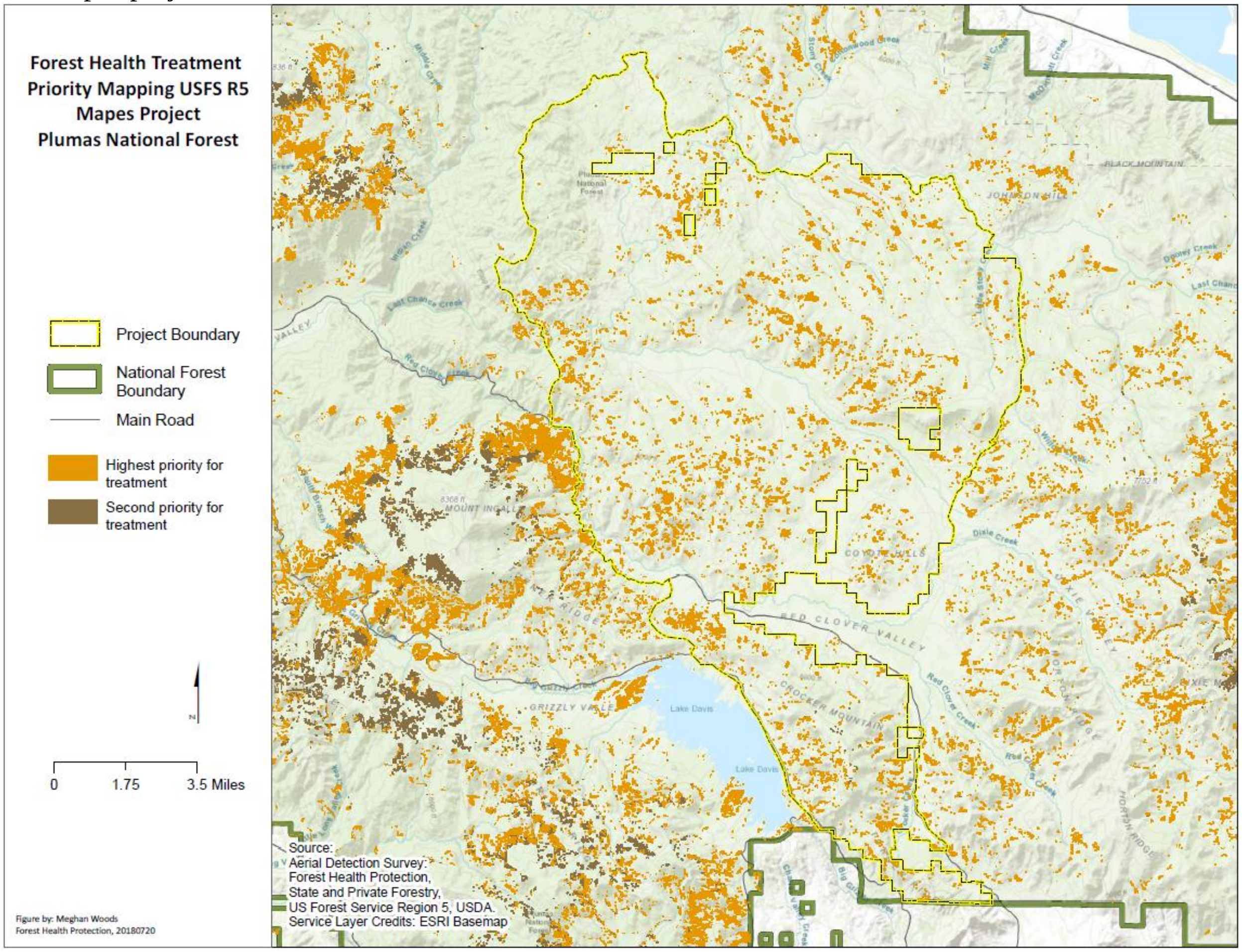
Considerations for Rx fire

If prescribed fire is used as a follow-up treatment to stand thinning, it may result in unacceptable levels of tree mortality; depending on management objectives. This mortality most often occurs as a direct result of cambium or crown injury to individual trees during the fire. Mature ponderosa, Jeffrey and especially sugar pines are susceptible to lethal basal cambium damage during prescribed burns from the heat that develops in the deep duff and litter that accumulates at their bases. These duff mounds typically burn at a slow rate with lethal temperatures, causing severe injury to the cambium which girdles the trees. To protect individual high-value large diameter pine from lethal cambium damage, raking the duff away from the bases of these trees before burning (within 24” of the bole and down to mineral soil) is recommended.

Potential for funding thought the Western Bark Beetle Program

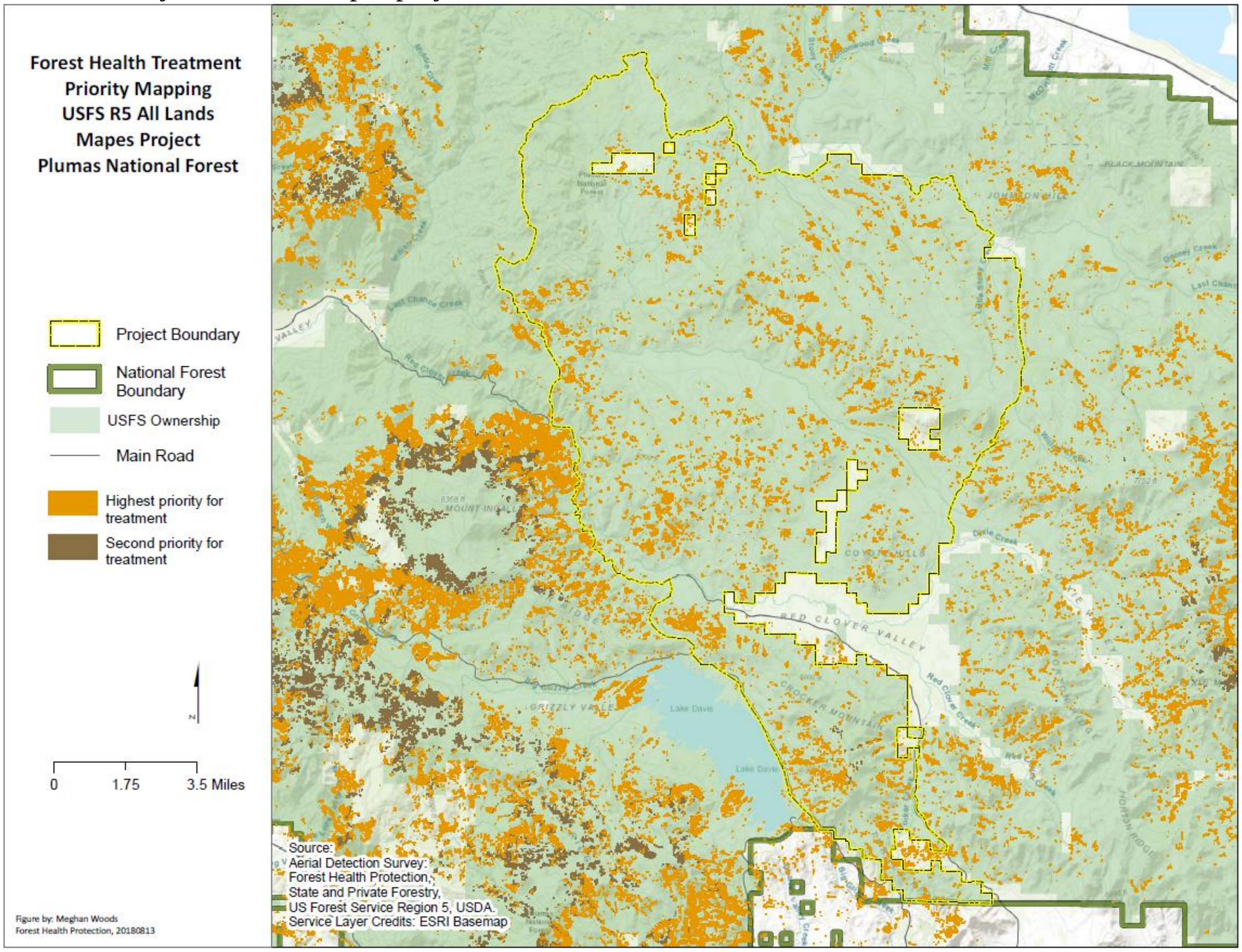
Forest Health Protection may be able to assist with funding, including NEPA activities, for thinning and removing green material from overstocked areas within the Mapes project area. Thinning treatments that reduce stand density sufficient to lower the risk to bark beetle-caused mortality would meet the minimum requirements for Western Bark Beetle Program funding and would be supported by this evaluation. If you are interested in this competitive funding please contact me for assistance in developing and submitting a proposal.

Figure 10. Treatment Priority Areas* at risk to bark beetle-caused tree mortality within and adjacent to the Mapes project area.



*Highest priority treatment areas include overly dense stands (>60% of maximum stand density index) of pine and pine-dominated mixed conifer stands as well as fir-dominated mixed conifer and white fir stands growing on historically pine-dominated sites. Second priority treatment areas include overly dense stands of fir-dominated mixed conifer and white fir. Mapped areas only include CWHR size class 4, 5 and 6 stands. Wilderness areas, inventoried roadless areas, wild and scenic areas, spotted owl protected activity centers, moderate to high severity burned areas since 1998, areas thinned since 2005, areas with >35% slope and all non-National Forest System lands were excluded from this analysis.

Figure 11. Treatment Priority Areas (ALL LANDS version)* at risk to bark beetle-caused tree mortality within and adjacent to the Mapes project area.



*Highest priority treatment areas for ALL LANDS version include overly dense stands (>60% of maximum stand density index) of pine and pine-dominated mixed conifer stands as well as fir-dominated mixed conifer and white fir stands growing on historically pine-dominated sites. Second priority treatment areas include overly dense stands of fir-dominated mixed conifer and white fir. Mapped areas only include CWHR size class 4, 5 and 6 stands. Moderate to high severity burned areas since 1998, areas thinned or that experienced stand replacing disturbance such as clear cuts or bark beetle-caused tree mortality since 2005 were excluded from this analysis.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431.

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Forest Health Protection, Regional Office

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<u>Insect and Disease Information</u>

<u>Fir Engraver</u>

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater that 4" in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Western Pine Beetle

The western pine beetle, *Dendroctonus brevicomis*, has been intensivly studied and has proven to be an important factor in the ecology and management of ponderosa pine thoughout the range of the host species (Miller and Keen 1960). This insect breeds in the main bole of living ponderosa pine larger than about 8 inches DBH. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latidude and elevation, there can be from one to four generations per year.

Evidence of Attack

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pitch tubes are formed on the tree trunk around the entry holes. Successful pitch tubes are red-brown masses of resin and boring dust. Relativly few, widely scattered white pitch tubes usually indicate that the attacks were not successful and that the tree should survive. Pheremones released during a successful attack attract other conspecifics. Attracted beetles may then spill over into nearby apparently healthy trees and overwhelm the tree with sheer numbers.

Life Stages and Development

These beetles pass thorugh the egg, larval, pupal and adult stages during a life cycle that varies in length dependent primarily on temperature. Adults bore a sinuous gallery pattern in the phloem and the female lays eggs in niches along the sides of the gallery. The larvae are small white grubs that first feed in the phloem then mine into the middle bark where they complete most of their development. Bluestain fungi inoculates the tree during successful attacks, blocking trachids and vessicles which contribute to the rapid tree mortality associated with bark beetle attacks.

Conditions affecting Outbreaks

Outbreaks of western pine beetle have been observed, and surveys made, in pine regions of the Westsince 1899 (Hopkins 1899; cited in Miller and Keen 1960). An insect survey completed in 1917 in northern California indicated that over 25 million board feet of pine timber had been killed by bark beetles.Information from surveys conducted in the 1930's indicated enormous losses attributed to the western pine beetle around that time. During the 1930's outbreak, most of the mortality occurred in stands of mature or overmature trees of poor vigor (Miller and Keen 1960). Group kills do not typically continue to increase in size though successive beetle generation as is typical with Mountain Pine Beetle and Jeffreay Pine Beetle. Rather, observations indicate that emerging beetles tend to leave the group kill area to initiate new attacks elsewhere.

The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In northeastern California, drought stress may be the key condition influencing western pine beetle outbreaks. When healthy trees undergo a sudden and sever moisture stress populations of western pine beetle are likely to increase. Healthy trees ordinarily produce abundant resin, which pitch out attacking beetles, but when deprived of moisture, stressed trees cannot produce sufficient resin to resist the attack. Any condition that results in excessive demand for moisture, such as inter-tree completion, competing vegetation, or protracted drought periods; or any condition that reduces the ability of the roots to supply water to the tree, such as mechanical damage, root disease or soil compaction, can cause moisture stress and increase susceptibility to attack by the western pine beetle. Woodpeckers, predacious beetles, and low temperatures act as natural control agents when beetle populations are low (endemic populations).

Heterobasidion Root Disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species: *Heterobasidion occidentale* (also called the 'S' type) and *H. irregulare* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregulare* (‘P’ type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentale* (‘S’ type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentale* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf mistletoe

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains

throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

White pine blister rust

White pine blister rust is caused by *Cronartium ribicola* an obligate parasite that attacks 5-needled pines and several species of *Ribes* spp. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on *Ribes* spp. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to *Ribes* spp. where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other *Ribes* spp. throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on *Ribes* spp. leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to *Ribes* spp. to continue the cycle. Although blister rust may spread hundreds of miles from pines to *Ribes* spp., its spread from *Ribes* spp. back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers that have margins more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.

California Flatheaded Borer

The California flatheaded borer, *Phaenops californica*, principally attacks Jeffrey and ponderosa pines, although it may be found in other pines.

It is most severe in stands located on sites where environmental stress is common. Decadent or unhealthy trees are most frequently attacked, along with an occasional top of a thrifty, vigorous tree.

Eggs are laid in bark crevices of the host tree. Newly hatched larvae penetrate directly through the bark to the phloem. Here the larvae may feed from a few months to 4 years without any apparent effect on the host tree. Should host vigor and larval abundance not allow them to succeed, the larvae cut very short galleries before they die. These galleries do not seriously injure the tree and are overgrown by the cambium. Should conditions be, or become, favorable for the larvae and unfavorable for the tree, the larvae develop rapidly and destroy the cambium.

Although this insect can kill trees weakened by dwarf mistletoe and root disease, its primary importance is rendering trees increasingly susceptible to bark beetles.